Volume 46 NOVEMBER-DECEMBER, 1960 Number 10

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

This Issue

AUTOMOTIVE ENGINES IN "LIGHT-DUTY" SERVICE

PUBLISHED BY
TEXACO INC.
TEXACO PETROLEUM PRODUCTS

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Published by

Texaco Inc., 135 East 42nd Street, New York 17, N. Y.

Vol. XLVI November-December, 1960 No. 10

Change of Address: In reporting change of address kindly give both old and new addresses.

Automotive Engines In "Light-Duty" Service

TODAY'S automotive power plants are highly developed devices which must perform well over an extremely wide range of operating conditions. They must accommodate rapid transient changes over a speed range of ten to one and deliver power levels upon demand which vary as much as fifty to one. In order to provide this high level of performance, the modern American standard size passenger car engine has become a relatively high-displacement, high-power output unit. Much of the time, however, in today's suburban living, these power plants are used for short trips where speeds are low and the driving is "stop-and-go" due to traffic congestion and traffic controls. One survey has shown that two-thirds of all car "trips" are of less than eight miles. Another found that approximately 85 per cent of the mileage accumulated by the motorist today is short-run driving. This type of service is generally (but erroneously) referred to as "light-duty" service. While most car owners will readily recognize that "light-duty" service has become an increasingly dominant part of the American motoring picture, some additional figures may be of interest to the statistically-minded reader:

(1) The number of two-car families has grown rapidly. In 1948, 6.7 per cent of the privately owned passenger cars were accounted for by two-car families; by 1957, this percentage had increased to 24.3% and is probably even higher today.

(2) In 55 per cent of all trips, the average car carries the driver only. Average load per trip, including children, is 1.80 passengers.

(3) The average annual mileage per car *decreased* from 9948 miles in 1946 to 9357 in 1956.

Thus the average American car is largely a convience used in such "light-duty" service as commuting, shopping and chauffering children to and from school.

LIGHT DUTY SERVICE LUBRICATION PROBLEMS

Short trip, stop-and-go driving requires only a fraction of the power available in modern engines which is illustrated by the difference between the typical level-road and full-throttle power curves of Figure 1. (It should be pointed out, however, that this difference represents a reserve of power which provides acceleration, and hill-climbing ability.) Cooling systems of these engines must have adequate capacity for high output operation under high ambient temperatures; in "light-duty" service this capacity tends to result in overcooling — or prolonged warmup. Figure 2 shows that in a modern V-8 engine, coolant outlet temperature just reaches the thermostatically controlled value after 4 miles, while engine oil temperature may not stabilize in less than 12 miles of slow-speed level-road driving. Since some 50 per cent of all trips are of less than

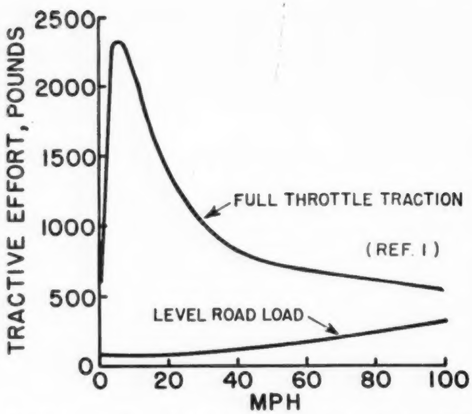


Figure 1 — Power available at rear wheels of a modern V-8 engine compared to level road power requirements.

4 miles duration[2] and since there is usually some cooldown time between trips, some engines may go for long periods of time without ever becoming completely warmed-up.

Under the partially warmed-up conditions which prevail in "light-duty" service, appreciable quantities of unburned fuel, incomplete combustion products, and moisture escape past the piston rings as indicated in Figure 3 and condense on the relatively cool pans and covers. Under low speeds and low temperatures, there is insufficient crankcase ventilation to sweep these contaminants out of the crankcase. Three major harmful effects result from these contaminants:

(1) Corrosive wear — primarily attack by acids formed from products of combustion. Main targets of this attack are the piston rings and cylinder walls.

(2) Formation of sludge and varnish deposits.

(3) Rusting. The acids and moisture contaminants can cause rusting throughout the engine, especially cylinder bores and hydraulic valve lifters.

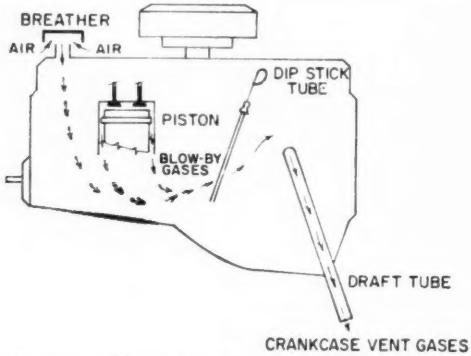


Figure 3 — Schematic showing crankcase ventilation and blow-by gases.

Engine manufacturers and car owners (although the latter may not realize it) rely heavily on the lubricating oil to protect passenger car engines from these harmful effects. As indicated by the use of quotation marks the term "light-duty" service, therefore, is a misnomer insofar as lubrication is concerned; actually this service is very severe from the point of view of the burden placed on the lubricant.

The remainder of this article will be a condensation of extensive laboratory and road studies that have been conducted to learn more about these "light-duty" problems and the capabilities and limitations of lubricants to combat them.

Corrosive Wear

Generally the useful life of automotive engines is limited by piston ring and cylinder wear. A major portion of this wear is *corrosive* wear accumulated during conditions of cold and partially warmed-up operation incident with stop-and-go "light-duty" service. The literature[5] amply supports this.

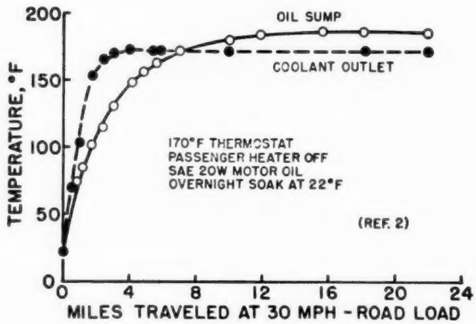


Figure 2 — Oil and coolant warm-up times.

Figure 4 shows that as water jacket temperature is decreased, wear increases at an accelerated rate. These data were obtained in a laboratory single-cylinder gasoline engine representative of modern automotive design, using the radioactive piston ring technique[3] for measuring wear rate. The slope of the temperature dependence line shown in Figure 4 (which, incidentally, has been confirmed by a number of investigators) amounts to a 2 to 1 increase in corrosive wear for a 25°F jacket temperature decrease at 100°F. Lines of the same slope were obtained with a number of oils, the differences among oils being merely a difference in level of wear[4]. Corrosive wear is the result of chemical

[2] Reference numbers on figures and in text refer to bibliography.

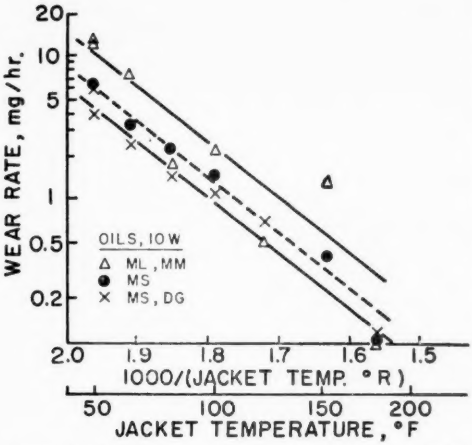


Figure 4 — Dependence of corrosive wear rate on jacket temperature.

action, primarily attack by acids formed from water vapor, carbon dioxide (CO_2), and other combustion products.

Wear Reduction by Lubricating Oil Additives

Corrosive ring and cylinder wear can be greatly reduced by alkaline lubricating oil additives which neutralize the acids formed from the products of combustion. Another protective action of some additives is their ability to adsorb onto the metal surfaces, forming a diffusion or surface-protecting barrier against the corroding acids.

The effect on low temperature wear of certain additives which have been prominently used in motor oil formulations is shown in Figure 5. The barium *phenolate* referred to in this figure is a salt of a strong base and a weak acid, and for that reason, all of the barium in the phenolate "appears" alkaline to acids with the strength of those causing corrosive wear. This type of additive, however, does not form an effective surface-protecting film on metal surfaces. The *normal* barium *sulfonate* has no alkalinity, but it does protect metal surfaces by forming an adsorbed surface-protecting film. The *basic* barium sulfonates are alkaline. The Total Base Number (TBN) shown on the abscissa of Figure 5 is a measure of alkalinity. It is apparent from this figure that wear decreases with increasing alkalinity for both the phenolates and the sulfonates. The difference in wear level between the phenolate and sulfonate, for a particular alkalinity level, is attributed to the surface-protecting ability of the sulfonate[4].

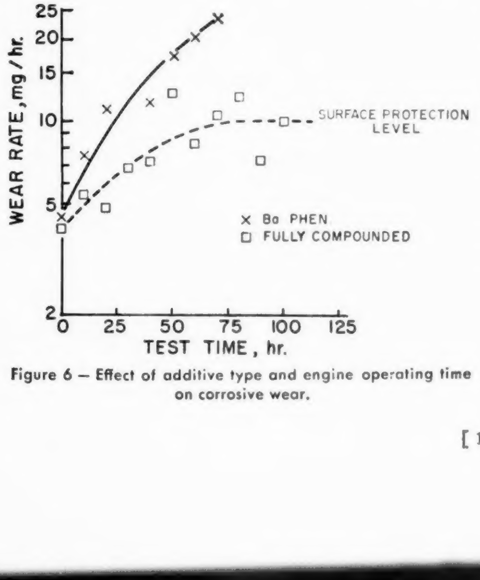


Figure 6 — Effect of additive type and engine operating time on corrosive wear.

The data presented in Figure 5 essentially show the influence of lubricating oil additives on low temperature ring wear using *new* oil. In actual consumer practice, however, the great bulk of operation is with oils which have been used for hundreds of miles. Figure 6 illustrates results obtained by making extended runs on a single oil charge in the radioactive ring wear test[4]. These

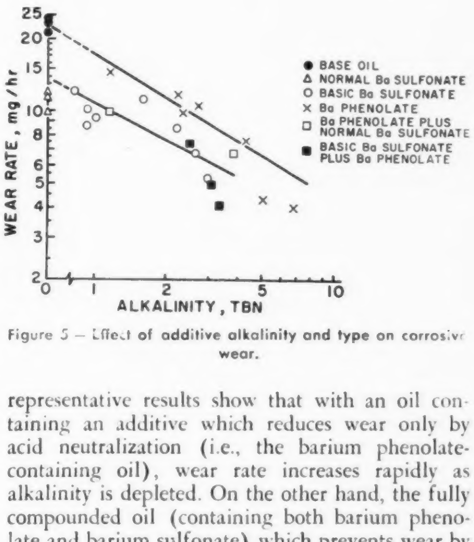


Figure 5 — Effect of additive alkalinity and type on corrosive wear.

representative results show that with an oil containing an additive which reduces wear only by acid neutralization (i.e., the barium phenolate-containing oil), wear rate increases rapidly as alkalinity is depleted. On the other hand, the fully compounded oil (containing both barium phenolate and barium sulfonate) which prevents wear by *both* acid neutralization and surface protection, shows a wear rate which increases only to the surface protection level as alkalinity is depleted. Thus, for short use of an oil, an alkaline oil with *no* surface protection may provide less wear than an oil providing *only* surface protection. However, with time the wear level of the alkaline oil will exceed the level for the surface-protecting oil (for example, after 70 hours of operation, the total top ring wear for a 0.3 per cent alkaline barium blend was 937 mg. in contrast to 734 mg. for a blend of a surface-protecting neutral sulfonate at 0.3

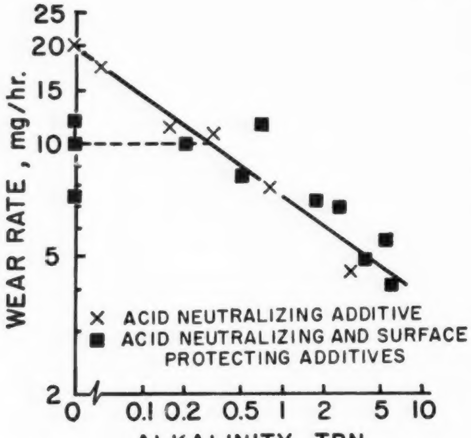


Figure 7 — Effect of alkalinity depletion on corrosive wear.

per cent barium. The combination of both the alkalinity and surface protection reduced the wear to 496 mg.). Runs with oils containing only surface-protecting additives have been carried out to the point where engine performance was degraded due to accumulated wear, yet no change in wear *rate* was observed. It is apparent that for prolonged operation, the oil additive should provide considerable surface protection in addition to alkalinity.

The wear rate data of Figure 6 are replotted in Figure 7 as a function of alkalinity of the crankcase oil as determined periodically during the run. The solid line for the barium phenolate blend (protection via alkalinity alone) shows that the wear rate for this type of oil continues to increase as alkalinity is depleted. The dashed line indicates the asymptotic approach of the wear rate for the fully compounded oil to the surface protection level after alkalinity had been depleted to a low level (about 0.3 TBN).

To obtain an estimate of the effective life *in consumer service* of the oil additives which protect against corrosive wear through acid neutralization, oil samples were obtained from a number of late model cars used in typical suburban passenger car service and analyzed for TBN. Total mileage on these cars at time of oil sampling ranged from a low of 2,997 miles to a high of 44,775 miles with the average being 21,195 miles. Oil samples were obtained as soon after an oil change and as close to 400 mile intervals thereafter as possible. Suitable precautions were taken to insure that representative samples were obtained.

The results of this survey are summarized in Figure 8 in terms of the anti-wear quality of the oil (TBN) as a function of mileage following an oil change. It will be noted that there is a considerable spread in TBN immediately following an oil change. This results from differences in TBN level of various grades of motor oil and from differences in the fraction of total oil replaced at an oil change. The fraction of total oil replaced varies from engine to engine because of variations in oil hold-up to sump capacity ratio. Further, this ratio, for any given engine, can be modified by changing the oil filter at the time of an oil change and by care on the part of the serviceman.

Of particular interest from the corrosive wear standpoint, are the indications from Figure 8 that in the most severe 15 per cent of the cars, a low alkalinity level (about 0.3 TBN) was reached 800 miles after an oil change; even the least severe cars reach this reduced protection level in less than 2000 miles. Referring back to Figure 7, it is evident that to take full advantage of the wear reduction provided by modern oils, it is desirable to maintain TBN at an appreciable level. Combining this knowledge with the data of Figure 8, it is clear that for at least 15 per cent of the cars this means changing oil at least every 1000 miles, for over 50 per cent of the cars the oil should be changed at intervals of 1400-1500 miles and even for the least severe cars, oil drain periods should not exceed 2000 miles. These data confirm the wisdom and practicality of the most recent American Petroleum Institute recommendations on crankcase oil drain intervals:

In winter — every 30 days

In summer — every 60 days

But never to exceed 2000 miles

Sludge Deposits — Formation and Control

As was pointed out in the introductory paragraphs, the sludge formed in gasoline engines in "light-duty" service is largely derived from fuel combustion residues. Extensive studies have indicated that "light-duty" engine sludge occurs in the following manner:

1. Combustion chamber gases, containing partially oxidized fuel products, blow past the piston

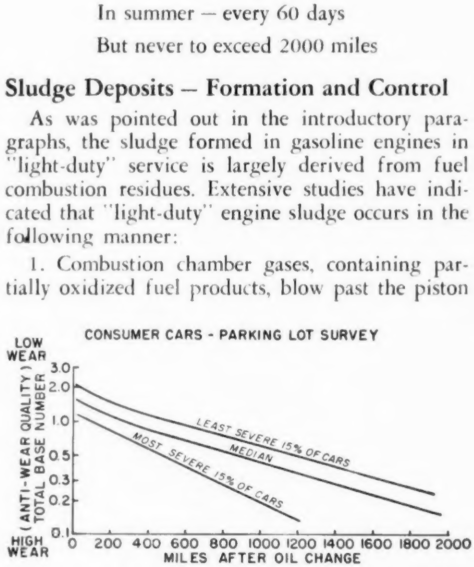


Figure 8 — The influence of mileage between oil drains on protection against corrosive wear.

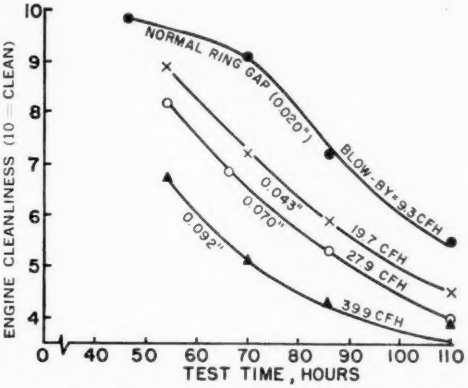


Figure 9 — Effects of test time and blow-by rate on sludge formation.

rings and condense on the cooler internal engine surfaces.

2. These condensed materials, perhaps after being further oxidized by nitrogen oxides and peroxides, are then polymerized on hot surfaces — the extent of the polymerization depending upon both the condensate concentration and the temperature environment within the engine.

3. The polymerized molecules entrained in the oil tend to coalesce into aggregates, which are held in suspension initially by detergent-dispersant additives. As the size and number of these aggregates increase, however, the dispersing media will become saturated and deposition of sludge will begin.

Engine operating conditions which increase the amount of partially oxidized fuel products passing to the crankcase result in increased deposits. For example, Figure 9 shows that as piston ring end gaps were increased on a modern single-cylinder engine used for lubrication research, the blow-by increased (thereby introducing more contaminants into the crankcase) and deposits increased. The deposit ratings on this figure are obtained from a merit rating system in which sludge throughout the engine is measured on a volumetric basis. A rating of 10 indicates a perfectly clean engine. From 8 on down the scale, each successively lower number denotes a doubling of the amount of sludge from that of the preceding higher number.

Measurements of piston ring wear in passenger cars driven in short-trip service have shown an average piston ring end gap increase of about 0.002 inch per 1000 miles. While this is admittedly an oversimplification of the wear picture, it does serve as a guide in interpreting the data of Figure 9. Thus, the mileage equivalents of the various ring gaps shown on this figure are roughly 10,000 miles for 0.043 inches, 25,000 miles for 0.070 inches, and 35,000 miles for 0.092 inches. In other words, there is a pronounced tendency toward increased sludge formation, per unit of operating time, as mileage is accumulated in "light-duty" service.

Similarly, other engine conditions which increase the concentration of contaminants, such as the use of less volatile fuels and lower operating temperatures, result in increased deposits. Figure 10 illustrates the effect of cold-cycle jacket temperature on deposits in a modern V-8 engine. This engine was operated on a temperature-cycling schedule simulating a period of low temperature light-duty operation followed by a short period of higher temperature operation; this cold-hot cycle was repeated for a total running time of 78 hours. It is obvious that deposits increased as the cold-cycle temperature was decreased. Similar data have been obtained on other engines and the relationship in Figure 10 is not unique. With all these engines, the lower operating temperatures cause greater condensation of the combustion products, thereby increasing the amount of contaminants in the crankcase oil.

Assuming there is sufficient low-temperature light-duty operation to contaminate the oil with combustion debris, the amount and character of the deposits can be influenced by conditions which favor polymerization of the condensed contaminants. Higher operating temperatures tend to promote this type of reaction. Polymerization, which produces high molecular weight oil contaminants from blow-by gases, also leads to the deposition of varnish-like materials on engine parts. These varnish deposits can function as "binders" which tenaciously hold particulate matter, leading to the accumulation of sludge. Thus, an individual driving his car all week in short trip, stop-and-go service, followed by some open highway driving at fully warmed-up temperatures for two to three hours over the week-end, is producing conditions within the engine which are very conducive to the formation and accumulation of sludge.

For the reader who may be skeptical of labora-

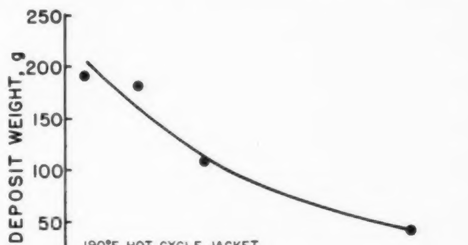


Figure 10 — Effect of coolant temperature on sludge formation.

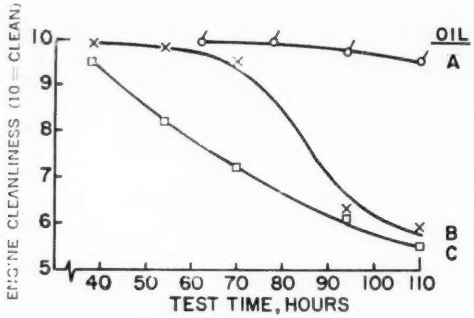


Figure 11 — Deposit-time curves for various additive oils.

tory engine data, it should be pointed out that inspection of consumer cars driven in mixed city-suburban operation verifies the above findings. For example, in one survey of sixty cars, selected to be a representative cross-section on the basis of car registration and make, it was observed that engine sludge increased with total mileage; above 25,000 miles, sludge accumulated more rapidly and, above 40,000 miles, a sizeable percentage of the cars were very dirty. Seven per cent of all cars inspected had oil screens completely plugged. Higher thermostat opening temperatures gave generally cleaner engines, and short trip operation gave dirtier engines.

Extensive data obtained in laboratory engines and road tests show that there are markedly different sludge deposition rates with different oils. The deposit-time curves of Figure 11 clearly indicate this fact. These data were obtained in a modern single-cylinder engine extensively used for lubrication studies (the same engine from which the data in Figure 9 were derived). The engine was operated under cyclic conditions simulating "light-duty" service. Inspections were made at regular intervals to develop information as to deposit accumulation with time. It will be noted that Oil "A" maintained a high level of cleanliness, with only a very light accumulation of deposits after 110 hours; with Oil "C", on the other hand, deposits build up much more rapidly; Oil "B" was able to maintain a high level of cleanliness for a short period after which there was an abrupt increase in deposits and "B" and "C" were about equivalent after 100 hours of test time. All three oils contained combinations of detergent-dispersant and inhibitor additives, but it is evident that the combination in Oil "A" provided distinctly superior performance.

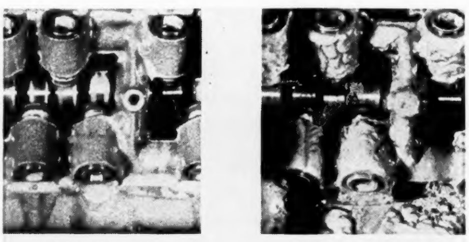
Figure 12 shows photographs of deposits in the valve lifter and camshaft region of a modern V-8 engine. These deposits illustrate what can happen with an oil which abruptly lost its ability to hold deposits in suspension. The left hand photograph was taken after 70 hours of cyclic "light-duty" operation and is representative of a highly satisfactory level of cleanliness. Deposits here amount to nothing more than an easily wipable film, with pools of oil in the cavities. The right hand photograph was taken with the same oil after 78 hours. The additional eight hours of operation resulted in heavy deposition of sludges and an obviously unsatisfactory level of cleanliness.

Data have also been obtained in actual road tests with a number of oils that had been previously evaluated in the laboratory single-cylinder engine. These data indicate that deposit accumulation in service is similar to that observed in the laboratory and further indicate that seventy hours of the laboratory single-cylinder engine operation is approximately equivalent to 3500 miles of severe "light-duty" consumer service. In the light of this knowledge, it is possible to utilize the single-cylinder engine with considerable confidence as to its significance in relation to consumer service. Thus with an oil having the characteristics of Oil "A" in Figure 11, it would be possible to obtain a high level of engine cleanliness in severe "light-duty" service with 3000 miles between oil changes; whereas with Oil "C", an oil change period of 1000 miles or less would be required to attain a cleanliness level approaching that of Oil "A".

Figure 13 presents a summary of road and laboratory engine deposit ratings on a group of commercial premium grade 10W-30 motor oils. Here again it will be observed that there is considerable variation from one brand to another but that both types of tests rate the oils in much the same relative order.

Engine Rusting

Although the problem of rusting of internal engine parts was recognized as one of the earliest problems encountered in automotive lubrication, the development and use of thermostats, improved crankcase ventilation systems, and improved oils all reduced the problem to tolerable levels for an extended period. In recent years, however, engine


SATISFACTORY
RATING = 9.5

UNSATISFACTORY
RATING = 0.2

Figure 12 — Comparison of good and poor levels of engine cleanliness.

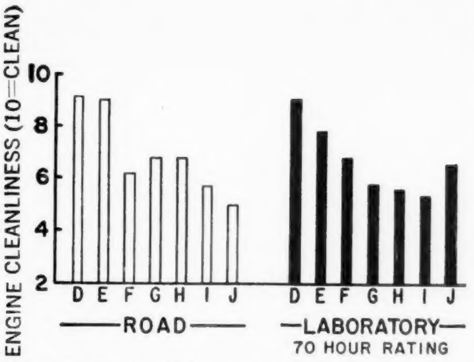


Figure 13 — Road and laboratory engine deposit ratings on a group of commercial 10W-30 oils.

rusting has been attracting increased attention, for the following reasons: (1) the increased number of cars and amount of driving being done under low temperature, low load conditions have resulted in greater probability of rust formation, (2) the increased use of close-fitting parts such as hydraulic valve lifters have increased the possibility of engine malfunctioning if rust should build up on these parts, and (3) the application of polymeric alkaline dispersants for "light-duty" deposit control favored the dispersion and emulsification of acidic combustion products, water and air thus creating an ideal environment for corrosive attack.

A number of investigators have conducted short-trip service tests within the last two years to learn more about this aspect of engine and lubricant performance. While these short-trip consumer-type tests varied in details, they have consistently shown that (1) engine rusting can occur very rapidly in some severe types of "light-duty" service, and (2) a wide variation in anti-rust quality is possible among oils used commercially.

One such test consisted of operating six recent model V-8 engine cars on a schedule which simulated consumer home-to-work driving (a 1.5 mile trip was made at 8 AM, 12 noon, 1 PM, and 5 PM, for a total of 6 miles of driving per day). The test was conducted during the months of March through June in a suburban New York area, and two premium type motor oils were evaluated. Table I summarizes the results after 300 miles of driving: photographs of typical lifters are shown in Figure 14.

Serious internal lifter rusting occurred in all engines charged with Oil "B", which, if allowed to continue, would probably have resulted in lifter malfunctioning within one oil drain period. In contrast, absolutely no lifter rusting was observed in any of the Oil "C" engines. Since three different makes of cars were involved, it also appears that engine rusting is quite insensitive to make of engine. Further, since the program was conducted during the moderately warm Spring months, it may be concluded that cold (Winter) temperatures are not essential for rust formation.

Figure 14 — Hydraulic valve lifter plungers after 300 miles of "home-to-work" driving on two different oils.

TABLE I
Hydraulic Valve Lifter Rusting After 300 Miles Home-to-Work Road Fleet

Car Make	Oil	Plunger & Internal Body Rust	Lifter Disassembly	Lifters Cold Stuck
X	B	Moderate to	Very diffi-	7
Y	B	heavy on all	cult on all	12
Z	B	three cars	three cars	13
X	C	None	Normal	None
Y	C	None	Normal	None
Z	C	None	Normal	None

On the basis of "consumer service" such as that described above, it has been possible to devise a rust test which can be run in the laboratory using modern V-8 engines on dynamometer test stands. This test provides the same ranking of oils with respect to rusting tendency as has been observed in field tests, but permits this evaluation in a much shorter period of time. As might be expected from the discussion in previous sections of this article, work in the laboratory has confirmed that rust formation tends to increase (1) as engine blow-by, fuel-air ratio, and carburetor air humidity are increased, and (2) as engine operating temperatures are decreased. Here again, the action of these variables is to increase the amount of contaminants which are potentially corrosive or otherwise harmful to metal surfaces.

Oils "B" and "C" in Table I were essentially identical in composition to Oils "B" and "C" of Figure 11. Of particular interest is the fact that Oil "B" is superior with respect to detergent-dispersant properties but is inferior with respect to anti-rust properties. However, research studies have shown that it is possible to markedly improve the rust-preventive characteristics of an oil, such as Oil "B", by the addition of a rust inhibitor. In fact by selection of a suitable inhibitor in the proper concentration, the anti-rust performance of Oil "B" can be improved to essentially equal that of Oil "C".

SUMMARY

It has been shown that in the short trip stop-and-go operation which prevails in so much of today's passenger car operation, only a fraction of the power available is required and engines seldom become thoroughly warmed-up. Under these conditions, large amounts of incomplete combustion products escape past the piston rings and find their way into the crankcase oil. A sequence of involved chemical reactions (details of which are imperfectly understood at present), initiated by these contaminants, can lead to corrosive wear of piston rings and cylinder walls, deposits of sludge-like material, particularly on cooler parts of the engine, and rusting of iron and steel surfaces throughout the engine. Corrosive wear shortens the useful life of an engine. Since blow-by increases as ring and cylinder wear is accumulated, the contamination of the crankcase oil and the rates of wear and sludge formation also increase. Thus, there is a "snowballing" of harmful effects as wear is accumulated. Sludge deposits can plug oil filters and oil lines, thereby interfering with normal oil flow; in the extreme, mechanical failure can result from such blockage of flow. Rusting of closely-fitting parts such as hydraulic valve lifters can lead to malfunctioning of such parts.

Where reasonably high quality lubricants are used, there is no material contribution to deposit formation from the lubricant itself under conditions of low temperature service. By the incorporation of carefully chosen additives in the base oil, it is possible to obtain a finished lubricant capable of combating the harmful effects of "light-duty" service. Selection of these additives is a complex process involving thousands of hours of testing[6]. Additives which are particularly effective in retarding deposition of sludge may not be adequate for protection against corrosive wear and rusting. Conversely, there are excellent anti-wear and anti-rust additives which do not have adequate detergent-dispersant properties: in fact some anti-wear and anti-rust additives when used in conjunction with good detergent-dispersant additives tend to degrade the cleanliness properties of the lubricant. Thus additive balance is particularly critical, and the factor of additive cost is ever present.

Since the flow of contaminants into the crankcase is a continuous process, the additives contained in a single fill of crankcase lubricant are depleted in the course of combating the contaminants. Research is continuing to develop additives that are even more durable and more effective than those presently available. However, at the present state of knowledge, to obtain the very excellent levels of protection and to insure the long trouble-free engine life which modern premium grade motor oils are capable of providing, the oil must be changed regularly and frequently on cars in severe "light-duty" service, not only to remove the accumulated contaminants from the engine, but to reestablish the oil's protective abilities.

BIBLIOGRAPHY

1. D. F. Caris and C. Marks, "Piston Engines in the Space Age", paper presented at API Division of Refining Meeting, May 1960.
2. P. A. Bennett, "Engine Rusting and the General Motors MS Test", presented at the ASLE Annual Meeting, April 1960.
3. "Application of Radioactive Tracers in the Petroleum Industry", *Lubrication*, December 1955.
4. T. H. Randall et al., "Lubricant Additive Action in Combating Low Temperature Wear in Automotive Engines", presented at SAE Fuels and Lubricants Meeting, November 1958.
5. "Fundamentals of Wear", *Lubrication*, December 1956.
6. "Development of a New Motor Oil", *Lubrication*, December 1958.

Printed in U. S. A. by
Salley & Collins, Inc.
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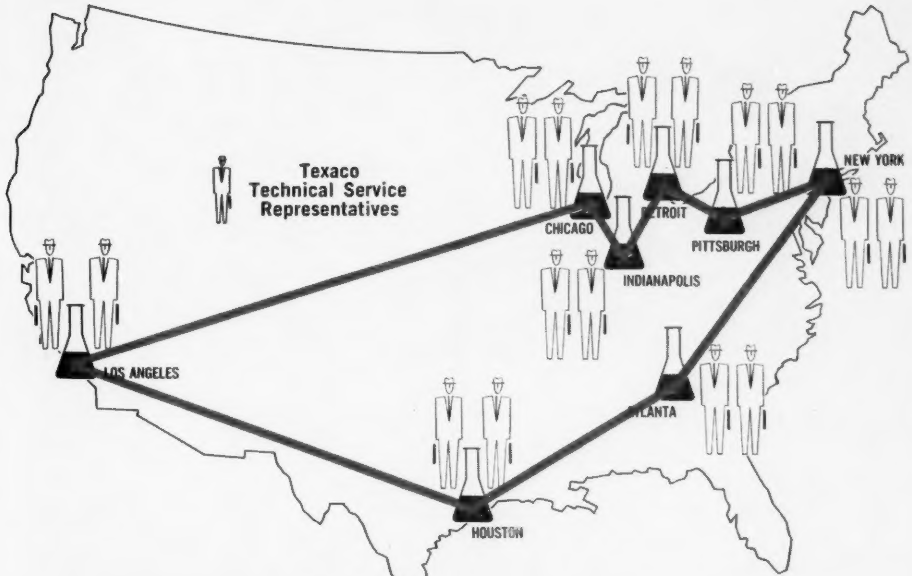
New York 17, N. Y.



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